VARIATION IN COB MORPHOLOGY AMONG CERTAIN ARCHAEOLOGICAL AND ETHNOLOGICAL RACES OF MAIZE

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INTRODUCTION

Zea Mays L., one of the most highly evolved of all grasses, is still botanically much of an enigma. Commonly known as Indian corn or maize, it was a very important plant to the peoples of the New World long before the arrival of Columbus. It formed the basis of the highly developed Inca, Maya, and Aztec civilizations and was the staple crop from Canada to Chile for several thousand years. It is, of course, quite important to the present-day inhabitants of Central and South America, and agriculture and industry in the United States uses three and one-quarter billion bushels annually.

Botanists have until recently followed almost exclusively Sturtevant's (1899) classification of contemporary races of maize by kernel types. Although this classification is an artificial one, it has proven to be of practical commercial worth. Archaeologists have long known the value of maize kernels found at excavation sites for determining types of maize grown and the uses to which they were put. Until the last few years, other parts of the maize plant have been quite generally neglected as a source of historical data, chiefly because of the complexities involved in determining and evaluating such evidence as they contain. Evidence from maize tassels has been used with promising results (Alava, 1952; Anderson, 1944b, 1944c, 1949a, 1951; Anderson and Brown, 1948; Anderson and Cutler, 1942; Brown *et al*, 1952; Cutler, 1946; Wellhausen *et al*, 1951, 1952). Prat (1948) showed that in maize and other grasses hairs and other epidermal emergences can be used as a basis for identification and classification. Internode patterns have been studied by several workers (Anderson, 1943, 1949a; Anderson and Brown, 1948; Anderson and Schregardus, 1944; Stonor and Anderson, 1949; Wellhausen *et al*, 1951, 1952). Ear and tassel ontogeny have been studied by Bonnett (1940, 1948) and Kiesselbach (1949). Esau studied the ontogeny of the maize vascular bundle.

Surprisingly little has been done to measure and evaluate those morphological structures which are present on a maize cob after the kernels have been removed. Weatherwax, a pioneer in the study of the maize cob, pointed out (1918) the need and value of accurate morphology in understanding this structure, and demonstrated (1920) the orderly spikelet behavior underlying changes in kernel rowing. Fujita (1939) observed that an even number of pairs of kernels resulted in straight rows, and an odd number in spiral rows. Cutler (unpublished work) made many histological studies of the cobs of both North and South American maize, as well as of several closely related genera. Lenz (1948) indicated the types

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of evidence available from a histological study of the maize cob. Alava (unpublished work) modeled in great detail small portions of the exterior surface of a maize cob. Mangelsdorf and Smith (1949) tabulated a number of external and internal maize ear characters, and their general procedure was used in characterizing 25 present-day races of maize in Mexico by Wellhausen *et al* (1951, 1952). These studies were based on the evaluation of many characters which did not involve exact measurements. In the present study, the value of several morphological characters used by these investigators has been increased by employing exact measurements. Other measureable morphological characters have been found which are of significance in tracing historical influences of one race of maize upon another.

There are two reasons why evidence present on the maize cob is important. The first one is based on the generally accepted fact that distinguishing characters are not distributed at random among plants; with regard to their occurrence in the Maydeae, agrostologists have found the female inflorescence to be of particular significance. The second reason, already pointed out by Lenz (1948), is that there are more archaeological remains of maize cobs than of any other plant material. The importance of these remains can perhaps be appreciated when one considers that maize, unlike most cultivated crops, is completely dependent upon man for its preservation. This fact can only mean that it has had a constant association with man since its adoption as a food plant, and that in its manner of origin, in the course of its migrations, in its development into a myriad of races, and in its intimate association with ancient religious symbolism, the history of maize becomes intimately tied to the history of man. Increased insight into the one will certainly add to our present understanding of the other.

For a reasonably complete investigation of the maize cob, the following three courses were deemed necessary: (1) to measure certain easily-recognized features of the maize cob and to interpret their morphological nature; (2) to set forth one possible scheme of analysis of the variation patterns of different races of maize based on these measurements; (3) to discuss the resulting indicated trends as to their validity and applicability in extending our present understanding of the history of maize.

Morphology of the Ear

Bearing in mind that an adequate treatment of variation in maize ears would be more complete if the nature of those parts under discussion were understood, a detailed study of morphological structures found on the maize ear was first undertaken. However, since the results are of a technical nature quite different from those obtained from a study of variation, they are treated elsewhere (Nickerson, in press).

MORPHOLOGICAL STRUCTURES EXAMINED

One of the purposes of this study in variation is to determine what morphological structures expressed in the cob are of significance in differentiating between races of maize. To accomplish this, several characters had to be included which ultimately proved to be of little use. A total of 526 cobs was examined for each of the three external and five internal characters discussed below.

EXTERNAL CHARACTERS

Shape of Ear.—This character is the only one used in the investigations which is dependent upon a subjective grading. Ears were classified into one of four types: straight, cigar-shaped, tapered, enlarged butt. Two of these types—straight and tapered—were used in analysis of each sample. For reasons discussed elsewhere (Nickerson, in press), a straight-eared race exhibits less condensation than a tapered- or enlarged butt-eared race, and a race with cigar-shaped ears is intermediate between these extremes.

Shank Diameter.—The diameter of the shank was measured in millimeters at a point close to the base of the ear, above the last apparent husk node whenever possible. In specimens with elliptical shanks, two measurements were made and an average of these was used. Shank diameters are fairly consistent within any one kind of maize and are often markedly divergent between different kinds.

Row Number.—Row number was determined by counting the number of vertical rows of glumes in the middle area of the cob. The middle area was used for this and all subsequent measurements because of its uniformity of size, stage of development, and freedom from growth irregularities common at both base and tip of the ear. Row number is a readily-observed character the importance of which is not yet fully understood. Anderson and Brown (1948) were able to correlate the condensation index of the tassel with kernel row number in the ear. Cutler (1952) used row number in his preliminary study of cobs from successive layers of cultural remains found in Tularosa Cave. His tables indicated the presence of high row numbers in lower strata and progressively lower row numbers in successively higher strata. These data show the reverse of the situation reported for the stratified remains of Bat Cave by Mangelsdorf and Smith (1949), who stated that in general the older (and more pod-corn-like) the ear, the lower was its row number.

INTERNAL CHARACTERS

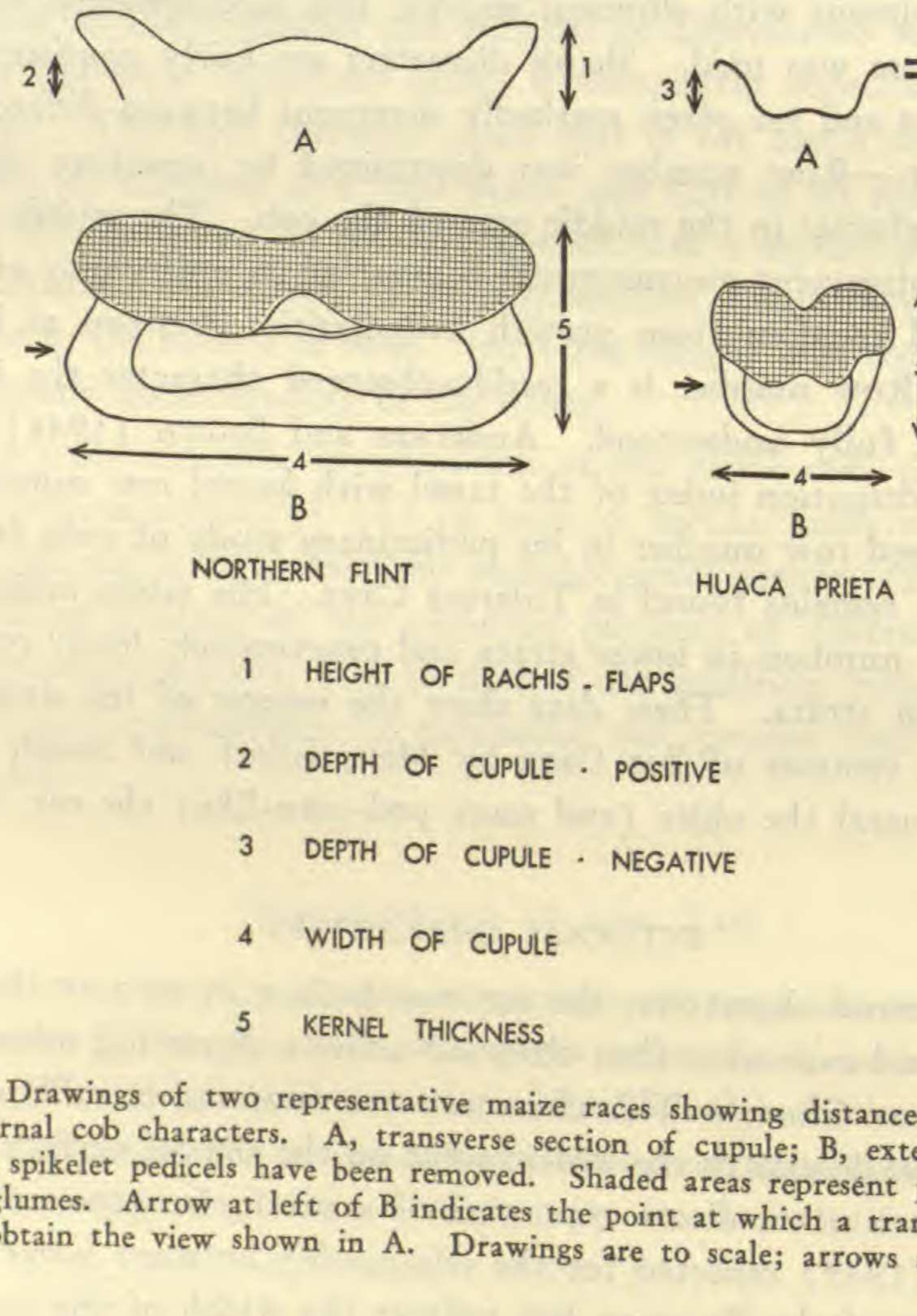
To study internal characters, the ear was broken in two at the approximate middle; the exposed ends were then observed under a dissecting microscope.

Width of Lower Glume.—This character was measured in millimeters with the calipers held perpendicular to the widest point on the abaxial surface of the glume. The measurement is not a direct expression of a particular gene such as Mangelsdorf and Smith (1949) reported for the relationship between lower glume length and various alleles of the *Tu* gene, but reflects the width of the basal portion of the kernel which it encloses.

Height of Rachis-flaps.—This measurement in millimeters was made perpendicular to the axis of the cob. In instances where the rachis-flaps were of unequal height, an average measurement was used. The rachis-flap is a part of the cupule (Nickerson, in press) and its significance is somewhat minimized by its variability in some otherwse homogeneous samples used in the present investigation. Mangelsdorf and Smith (1949) reported the same situation for maize cobs from Bat Cave, but Wellhausen *et al* (1951, 1952) found rachis-flaps to be extremely useful in characterizing races of maize in Mexico.

Depth of Cupule.—This measurement in millimeters was made perpendicular to the cob axis, and was given a positive or a negative value, depending upon whether it was out from, or down into the rachis. It represents the extent of adnation of the cupule-forming prophyll (Nickerson, in press) to the axis, and is well correlated with ear shape.

Width of Cupule.—This measurement was made by holding the calipers at right angles to the cob surface and measuring the distance in millimeters between



Text-fig. 1. Drawings of two representative maize races showing distances measured in determining four internal cob characters. A, transverse section of cupule; B, external view of cupule after glumes and spikelet pedicels have been removed. Shaded areas represent points of attachment of spikelets and glumes. Arrow at left of B indicates the point at which a transverse cut was made in each case to obtain the view shown in A. Drawings are to scale; arrows at 2 and 3 are each 1 mm. long.

any pair of outside rachis-flap edges across their cupule. It is in part an indication of kernel width, in that wide cupules always mean wide kernels.

Thickness of Kernel.—The distance along the cob axis from the base of one set of lower glumes to the upper edge of their cupule is exactly equivalent to the thickness of each kernel produced there. The measurement is useful in making comparisons between productivity of different cob samples, especially those involving fragmentary archaeological remains.

These last four characters were recorded in outline drawings carefully made to scale (working with calipers under a dissecting microscope) for each of the 526 cobs examined (text-fig. 1). Other characters measured but not used include height and texture of the lower glume and longitudinal profile drawings of each cupule. Diameters of the pith, cob, and rachis were measured and the cob/rachis index (Mangelsdorf and Smith, 1949), as well as the rachis/pith index, was computed for all specimens. However, neither the averages nor the individual variations of these indices were found to be particularly characteristic among the maize samples studied in this investigation.

Names, Sources, and Anthropological Background of Samples

Maize samples examined were of diverse origin both geographically and temporally. Races of contemporary maize here included were chosen as typical for those parts of the world. Archaeological cob samples were largely from the southwestern United States, but included one sample from Lower California and two extensive collections from sites excavated by Junius Bird in Peru and northern Chile. In listing the samples they are grouped arbitrarily into geographical units; no further inferences should be drawn from this arrangement. Samples, except where otherwise noted, are from the maize collection of the Museum of Economic Botany of the Missouri Botanical Garden, St. Louis.

NORTH AMERICA

Present-day Races:

Iroquois Sacred Flour.—This sample was from material originally grown by Professor Frank P. Bussell from seed collected by Erl Bates from the Iroquois Indian tribes of northern New York. The Indians grew it under conditions of strict isolation for ceremonial use (Anderson, 1947b). Ears are straight, 20–28 cm. long, with heavy shanks and 8 rows of wide white or yellow (sometimes pale blue) kernels. Fourteen ears were examined.

Northern Flint.—A composite sample, this group included flint corns from the Northeast (Parker's, Canada, Mammoth Yellow, Longfellow) and the upper Great Plains (Winnebago, Bear Island, Brownell, Mandan, Tama, Golden Chippewa). Brown and Anderson (1947) studied these and other representative flint varieties and reported that the ears were long and slender with 8–10 rows of wide, crescent-shaped kernels, heavy shanks, and a tendency toward a large cob base. Twenty-three ears were examined.

Hopi White Flour.—This sample was furnished by Dr. William L. Brown, Pioneer Hi-Bred Corn Co., Johnston, Iowa, who collected it at the Hopi town of Hotevilla, Arizona. Carter and Anderson (1945) considered Hopi White Flour to be an example of Puebloan maize. Brown *et al* (1952) reported that this variety is one of their main sources of meal. The straight ears are 18–24 cm. long, with wide shanks, no basal compression, and wide white kernels in 12–14 rows. Seven ears were examined.

Hopi Blue Flour.—Also furnished by Dr. William L. Brown, this collection has substantially the same history as Hopi White Flour. However, Brown *et al* (1952) reported that it is probably more important as a source of food. The cigar-shaped ears are 14–20 cm. long, with small shanks, a tendency toward basal compression, and 10–20 rows of narrow blue-aleuroned kernels with white endosperm. Eleven ears were examined.

Papago Flour.—This race of maize is grown by the desert-dwelling Papago Indians, and was reported by Carter and Anderson (1945) to be quite similar to prehistoric Basketmaker maize. The ground kernels make a meal of excellent quality. Ears are 20–25 cm. long, cigar-shaped, with narrow shanks and 12–14 rows of isodiametric yellow kernels with white endosperm. Twenty-five ears were examined.

Archaeological Remains:

Basketmaker.—Cobs included in this collection were recovered from Kinboko and White Dog Caves, both of which are located in Tsegi Canyon, Marsh Pass, northeastern Arizona. The samples were submitted by Mr. Harold S. Gladwin, who estimated their age to be *circa* 200–300 A.D. On the basis of there being no pottery associated with these cobs, they are believed to belong to the cultural level known as Basketmaker II. The cigar-shaped cobs are 6–12 cm. long, and bore somewhat isodiametric kernels in an average row number of 14. Six cobs were examined.

Marsh Pass.—Cobs included in this collection were recovered in West Hackberry Canyon and Turkey Cave, both of which are located in Tsegi Canyon, Marsh Pass, northeastern Arizona. These samples were also submitted by Mr. H. S. Gladwin, who estimated their age to be from 300 A.D. to about 1000 A.D. The collection represents cultural levels from late Basketmaker II or later up through Pueblo II. The predominantly cigar-shaped cobs are 6–14 cm. long, and bore kernels wider than thick in an average row number of 10. Thirty-one cobs were examined.

Turner Site.—This sample consisted of 50 cobs and fragments recovered from the Turner Site, near Cisco, Utah, by H. M. Wormington, Curator of Archaeology, Denver Museum of Natural History. Wormington estimates its age to be around 1000 A.D. (personal communication, 1953), and believes that the site was inhabited by peoples who were culturally a later manifestation of the Fremont Basketmakers. Remains of their culture were recovered from Castle Park in the

Yampa River Valley, Utah, and are dated at 400–800 A.D. by Burgh and Scoggin (1948). There are nearly equal numbers of tapered and cigar-shaped cobs in this collection; some were not used in this study because of their fragmentary nature. Cobs are short, 3–8 cm. long, charred, with medium shank diameters and medium-wide kernels in an average number of 12 rows. Twenty-seven cobs were examined.

Luster Cave.—Ten cobs were recovered by Dr. Robert Lister, Department of Anthropology, University of Colorado, Boulder, from a cave located in Utah, just west of the Colorado state line, in the Glade Park area. A preliminary report (Lister and Dick, 1952) described the archaeological finds of this cave and of other nearby sites. On the basis of pottery types, the maximum possible age assigned to Luster Cave by these workers is 900–1000 A.D., but it may be much more recent. The straight and tapered cobs are generally uncharred and fairly complete with small shank diameters and wide kernels in an average number of 10 rows. Nine cobs were examined.

Tularosa Cave.—More than 30,000 maize cobs were recovered from this site in Pine Lawn Valley, northeast New Mexico, by archaeologists from the Chicago Natural History Museum. The Museum has submitted these cobs to Dr. Hugh C. Cutler, who has generously made available for inclusion in the present study samples representing three levels of Square 3R2. Maize cobs from the lowest levels of Tularosa Cave were dated at 2300 ± 200 years by the Carbon 14 method. The cave is estimated to have been abandoned somewhere around 1000–1200 A.D., and thus was continuously occupied for about 1500 ± 500 years (Martin *et al*, 1952). Material from Square 3R2, Levels 3, 6, and 11 was studied as three separate samples, each of which was chosen so that the cobs analyzed reflected the proportionate row numbers determined by Cutler (1952) from all cobs found in each of these layers. There was a decrease in row number from the lower levels to the surface, average row numbers for Level 11 being 12–14, for Level 6, 10–12, and for Level 3, 8–10. Culturally, Level 11 is the oldest (400 B.C. ± 200 years) and represents the Pre-pottery Phase. Level 6 dates back to 500–600 A.D., and represents the Georgetown Phase. Level 3, at 1000–1200 A.D., represents the San Francisco Phase. Twenty-five cobs from each of the three levels were examined.

Point of Pines.—This sample consists of about 250 ears of charred maize. It was recovered from Room 50 of a large ruin at Point of Pines, Arizona, numbered Ariz. W:10:50, and was submitted by Dr. Emil W. Haury, Director, Arizona State Museum, Tucson, Arizona. He believes its age to be 1250 A.D. (personal communication, 1953). It can be assigned to the Pueblo II cultural phase. The straight and cigar-shaped ears are 5–8 cm. in length, with small shanks and smooth kernels wider than thick in an average number of 10 rows. Seventy-five cobs were examined.

MEXICO AND CENTRAL AMERICA

Present-day Races:

Chapalote.—This race of popcorn is considered by Wellhausen *et al* (1951, 1952) to be one of the ancient indigenous races of Mexico. It was mentioned by Anderson (1944a, 1946) as being allied to the primitive *Maíz reventador.* Wellhausen *et al* pointed out its resemblance to archaeological maize finds at Painted Cave (Haury, 1945) and Cottonwood Cave (Hurst, 1948; Hurst and Anderson, 1949). They considered it to be one of the most distinctive races of maize in Mexico. Mangelsdorf (1948) and Mangelsdorf and Smith (1949) regarded it as possessing the "weak" allele for pod corn. The cigar-shaped ears are 10–15 cm. long, with small shanks and smooth rounded chocolate-brown kernels in an average row number of 12. Ten ears were examined.

Guatemala Flint.—A common variety of the Guatemala highlands, this race was described by Anderson (1947a), who considered it to represent one of the basic elements in Guatemalan maize. Ears are 10–25 cm. long, with a conspicuously enlarged and irregularly rowed butt, heavy shanks, a heavily sclerenchymatized rachis, and wide flinty kernels (some of which are capped with soft starch) in 8 (occasionally 10 or 12) straight rows. Eleven ears were examined.

Archaeological Remains:

Lower California.—This sample of 52 maize remains was recovered from Cave B. C. 100, located 8–10 miles east-southeast of Comondu, in central Baja California, and was submitted by Dr. William C. Massey, Dept. of Anthropology, University of Washington, Seattle. The cobs were recovered from a layer dated by Dr. Massey at 1697–1750 A.D. (personal communication, 1953). The cigar-shaped and straight cobs are 6–12 cm. long, with small shanks, and bore nearly isodiametric kernels set in 10–12 rows. Thirty-five cobs were examined.

SOUTH AMERICA

Present-day Races:

Peru Flour.—This sample was collected by G. Edward Nicholson at Huancayo, Peru, where it was being offered for sale in one of the native markets under the name of "*Maíz de Color.*" It belongs to the race Cutler (1946) called "Valle Maize." Ears are short, tapering, constricted at the base, with small shanks. The race exhibits little sclerenchymatization. Kernel color varies from ear to ear; brown, red, yellow, and various delicate striped combinations are most common. Kernels are pointed, as wide as thick, and arranged in prominent rows averaging 10 per ear. Twenty-three ears were examined.

Coroico.—This race, described by Cutler (1946) as "the most unusual race so far known," has the odd characteristic of brick-like arrangement of "alicoles" (cupule plus pair of associated spikelets; Nickerson, in press). Cutler described the tapered ears as long, slender, and flexible (25–30 cm. lengths were common in the collection examined), with a light brown cob, small pith, and brown-orange kernels. He stated that the row number averaged 9, but he now believes (personal interview, 1953) that two successive rings of alicoles constitute a single diametral whorl; thus the row number of Coroico is generally high, averaging 18. Whether 9 or 18 rows are present is governed by the state of condensation of the cob axis. Twenty-five ears were examined.

Archaeological Remains:

Arica.—These samples were recovered from two midden sites, Playa Miller and Quiani, located on the coast in the vicinity of Arica, Chile (18° 30′ S. Latitude), by Junius B. Bird, Associate Curator of Archaeology, American Museum of Natural History, New York. Cobs from both sites were treated as one sample following Bird's (1943, 1948) suggestion that Playa Miller represented a continuation of sequences started at Quiani. The oldest maize remains from this area are dated at about the time of Christ (Bird, personal communication, 1952). It is thus younger than material from the Huaca Prieta sites discussed below. The cigar-shaped and tapering cobs are 5–12 cm. in length and 1–2.5 cm. in width, with small shanks and an average row number of 14. Twenty-one cobs were examined.

Huaca Prieta.—These samples, also from the American Museum, were recovered by Junius B. Bird from Huaca Prieta, a site on the Peruvian coast at the south of the Chicama Valley (app. 8° S. Latitude). These comprehensive samples consist of 604 cobs from Test 1 and 171 cobs from Test 5. The two groups were treated separately, since Bird regarded cobs from Test 5 as older than those from Test 1, and were designated Huaca Prieta 5 and Huaca Prieta 1, respectively. Cultures responsible for the Huaca Prieta middens began about 3000 B.C. (Bennett, 1948; Bird, 1948), but maize did not make its appearance there until 850 B.C. (Bird, personal communication, 1953). Implications as to archaeological and botanical significance of these finds are further discussed by Anderson (1947b), Carter (1950), and Whitaker and Bird (1949). The well-preserved, tapered and cigar-shaped cobs are remarkably uniform, especially those found in the lower levels, which have small shank diameters, an average row number of 14, and are horny rather than brittle or bony in texture. Thirty-five cobs from Huaca Prieta 1, representing 7 layers, and 44 cobs from Huaca Prieta 5, representing 5 layers, were examined.

ASIA

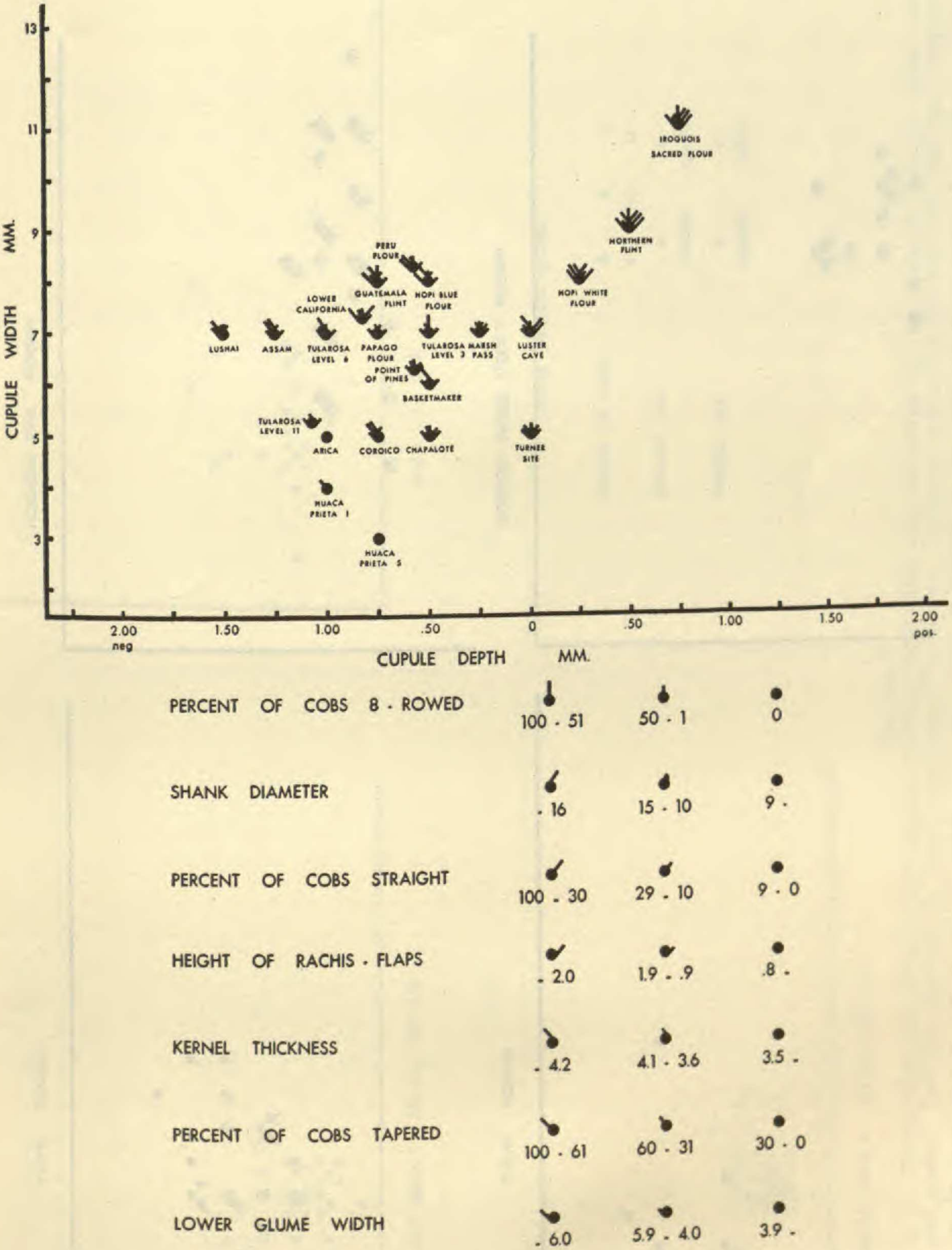
Assam and Lushai.—The samples from Asia were contributed by Stonor, who collected them in the hills of Assam. The history and morphology of varieties in this collection have been described by Stonor and Anderson (1949). The cobs used here were those actually raised in Asia. For this investigation they were separated into two groups: (1) *Assam,* which includes 21 cobs from tribes other than the Lushai; (2) *Lushai,* which includes 8 cobs representative of the maize varieties grown by the Lushai tribe. Cobs of both groups are sufficiently alike to

TABLE I

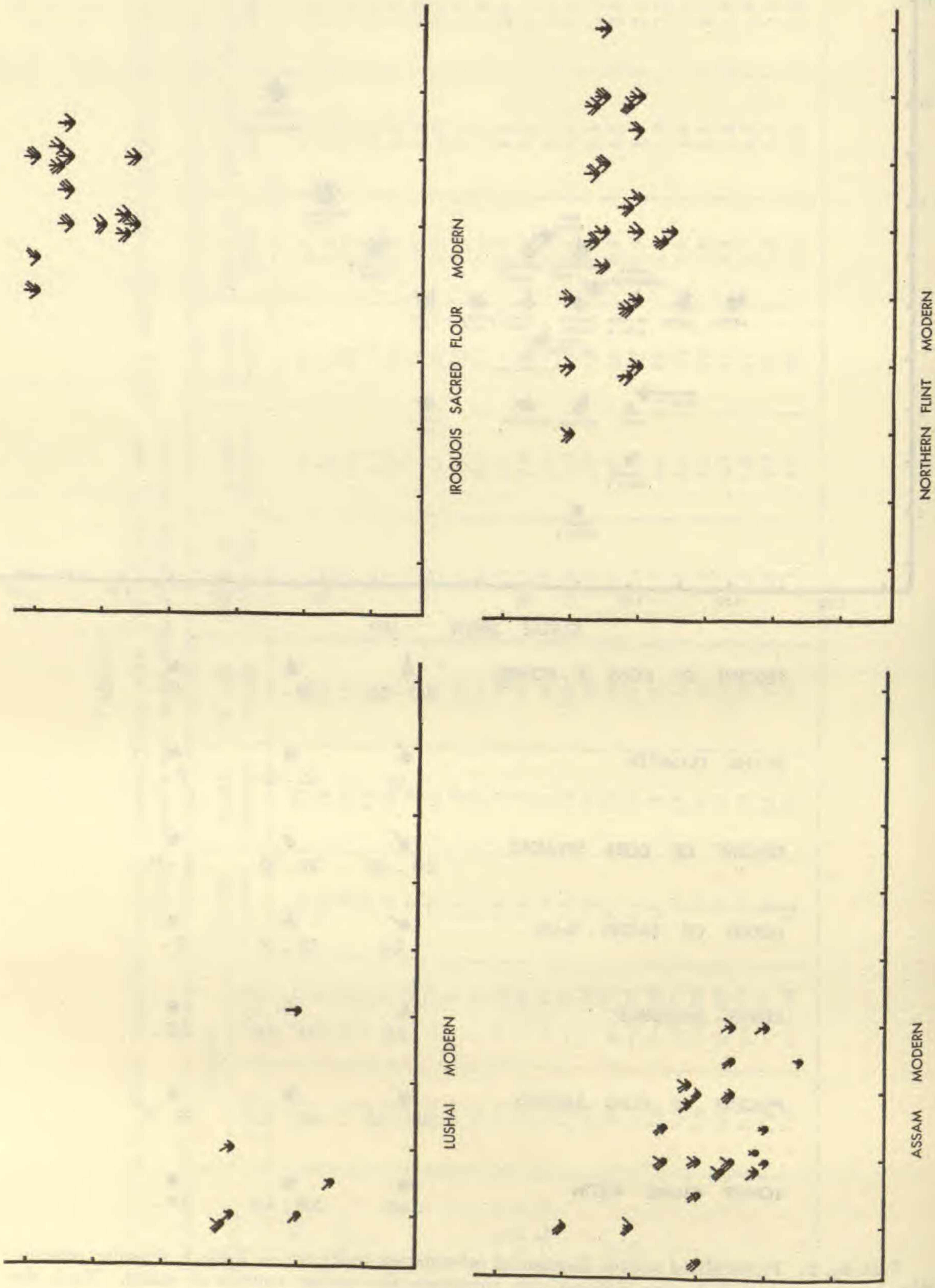
AVERAGE VALUES OF NINE MORPHOLOGICAL CHARACTERS AND TWO INDICES FOR EACH MAIZE COB SAMPLE STUDIED

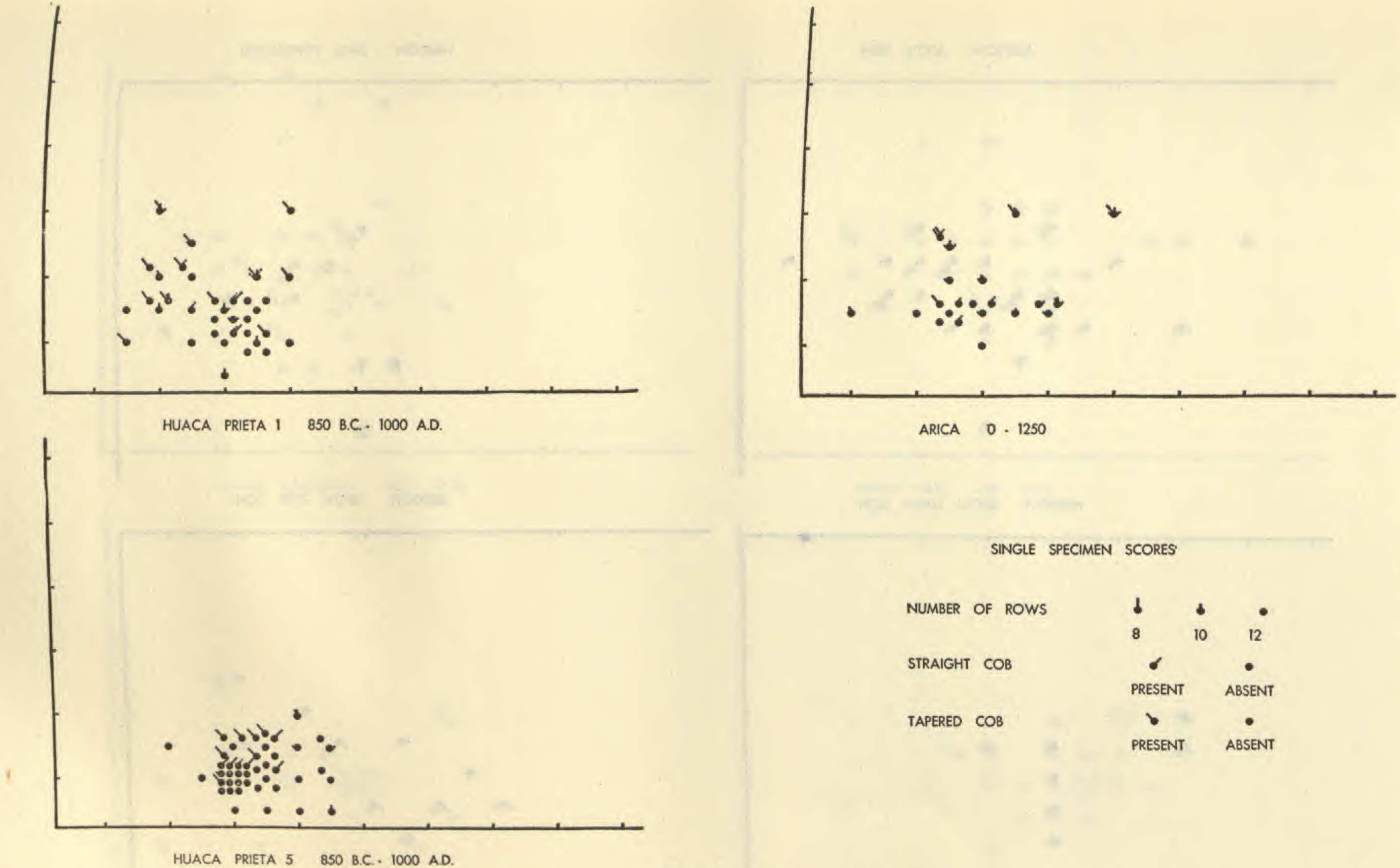
(Measurements in mm. except where otherwise indicated)

Name of Sample	Cupule		% cobs 8-rowed	Shank diameter	% cobs straight	Height of rachis flaps	Kernel thickness	% cobs tapered	Lower gl. width	Cob/rachis index	Rachis/pith index
	width	depth									
Iroquois Sacred Flour	11.5	+ .75	90	22	43	2.0	3.7	43	8.7	1.7	2.1
Northern Flint	9.5	+ .50	90	16	35	2.0	4.4	32	7.0	1.8	2.1
Hopi White Flour	8.5	+ .25	0	19	35	2.0	4.7	65	6.2	1.7	1.8
Hopi Blue Flour	8.5	— .50	20	12	35	1.6	4.2	0	5.8	1.9	1.8
Papago Flour	7.0	— .75	0	14	0	1.2	4.0	28	5.4	1.8	1.9
Basketmaker	6.0	— .50	0	9	0	1.5	4.3	16	4.4	1.6	2.0
Marsh Pass	7.5	— .25	20	11	16	1.5	4.1	20	5.5	1.5	2.1
Turner Site	5.5	0	11	8	12	1.0	3.0	50	3.7	1.3	1.7
Luster Cave	7.5	0	33	7	33	1.6	4.5	33	5.2	1.8	1.8
Tularosa Cave—L. 3	7.0	— .50	68	9	0	1.5	4.1	4	5.9	1.8	2.4
Tularosa Cave—L. 6	7.5	—1.00	16	7	4	1.3	4.7	48	5.5	1.7	2.3
Tularosa Cave—L. 11	5.5	—1.00	0	8	0	1.0	4.0	4	5.5	1.7	2.3
Point of Pines	6.5	— .50	32	8	20	1.2	3.6	3	5.5	1.7	2.0
Chapalote	5.5	— .50	10	9	0	1.0	4.0	10	5.4	2.1	2.5
Guatemala Flint	8.5	— .75	77	15	0	1.2	4.5	44	6.8	1.9	2.9
Lower California	8.5	— .75	14	8	37	1.3	3.8	27	5.9	1.8	2.1
Peru Flour	8.0	— .50	10	8	8	.9	4.0	92	5.0	1.9	2.2
Coroico	5.5	— .75	0	13	0	.5	6.6	95	5.9	1.9	2.1
Arica	5.0	—1.00	0	6	0	.5	3.2	30	3.5	1.6	2.1
Huaca Prieta 1	4.0	—1.00	0	4	5	.3	3.1	31	2.4	1.6	1.8
Huaca Prieta 5	3.5	— .75	0	6	9	.2	3.0	13	2.7	1.9	1.9
Assam	7.0	—1.25	0	12	0	.9	4.9	75	5.0	1.7	2.3
Lushai	7.0	—1.50	12	10	0	.5	4.0	75	6.0	1.9	2.0



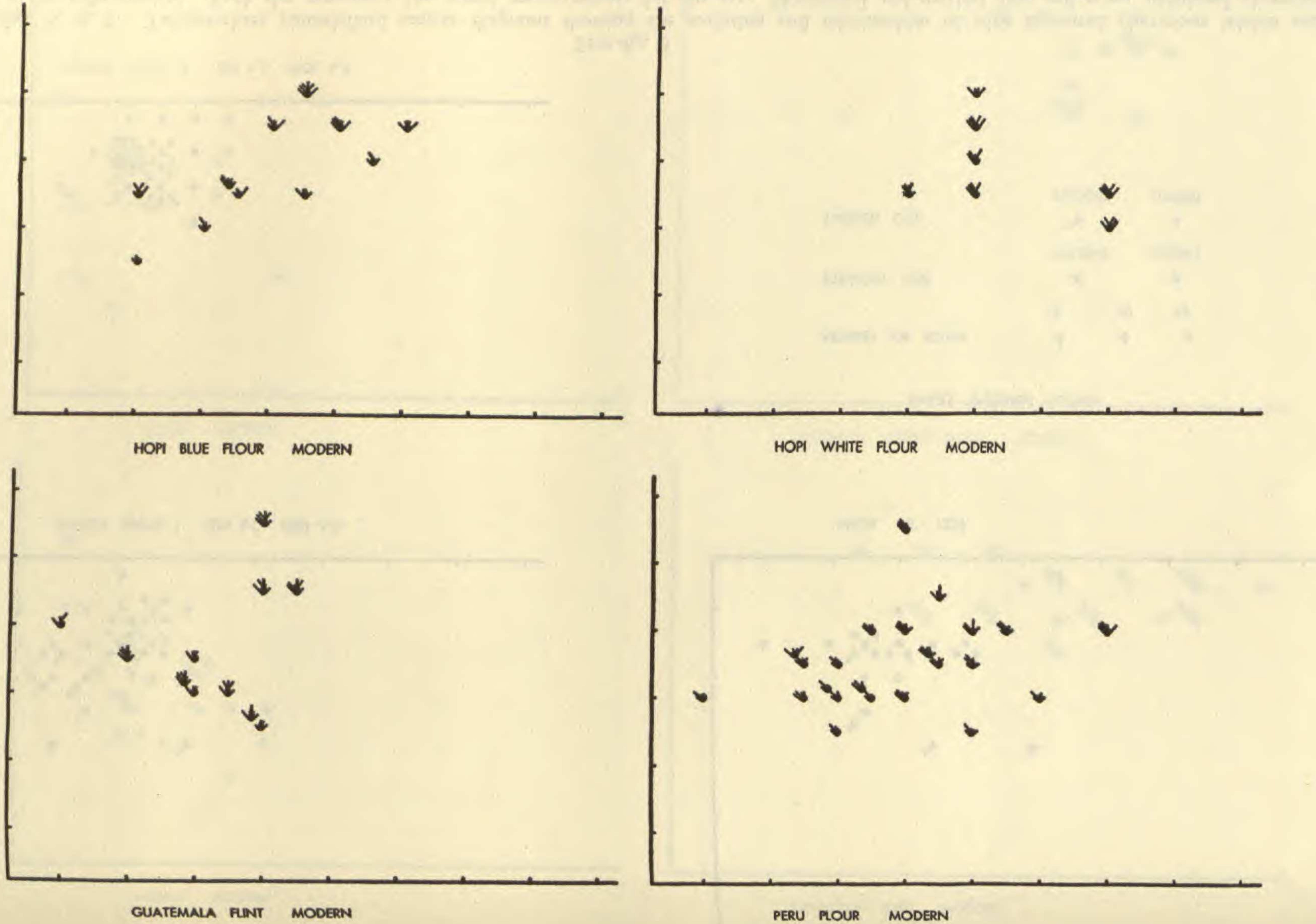
Text-fig. 2. Pictorialized scatter diagram of information contained in Table I, showing relationships between variation in nine different cob characters for various samples of maize. Each dot represents the mean for nine measured characters for all cobs studied in that group; horizontal axis, depth of cupule; vertical axis, width of cupule; seven other characters are diagrammed by rays, as explained on the figure. Further explanation in the text.


IROQUOIS SACRED FLOUR MODERN
NORTHERN FLINT MODERN
LUSHAI MODERN
ASSAM MODERN



Text-fig. 3

Text-figs. 3, 4, 5. Twenty-three pictorialized scatter diagrams showing the variation and relationships of nine measured characters within each group of maize cobs studied. Each dot represents the actual measurements for one ear. Horizontal and vertical axes and seven additional characters are scored as in text-fig. 2, except row number and cob shape, which were scored as indicated in the lower right-hand corner of text-fig. 3. Dotted ray indicates no measurement could be made.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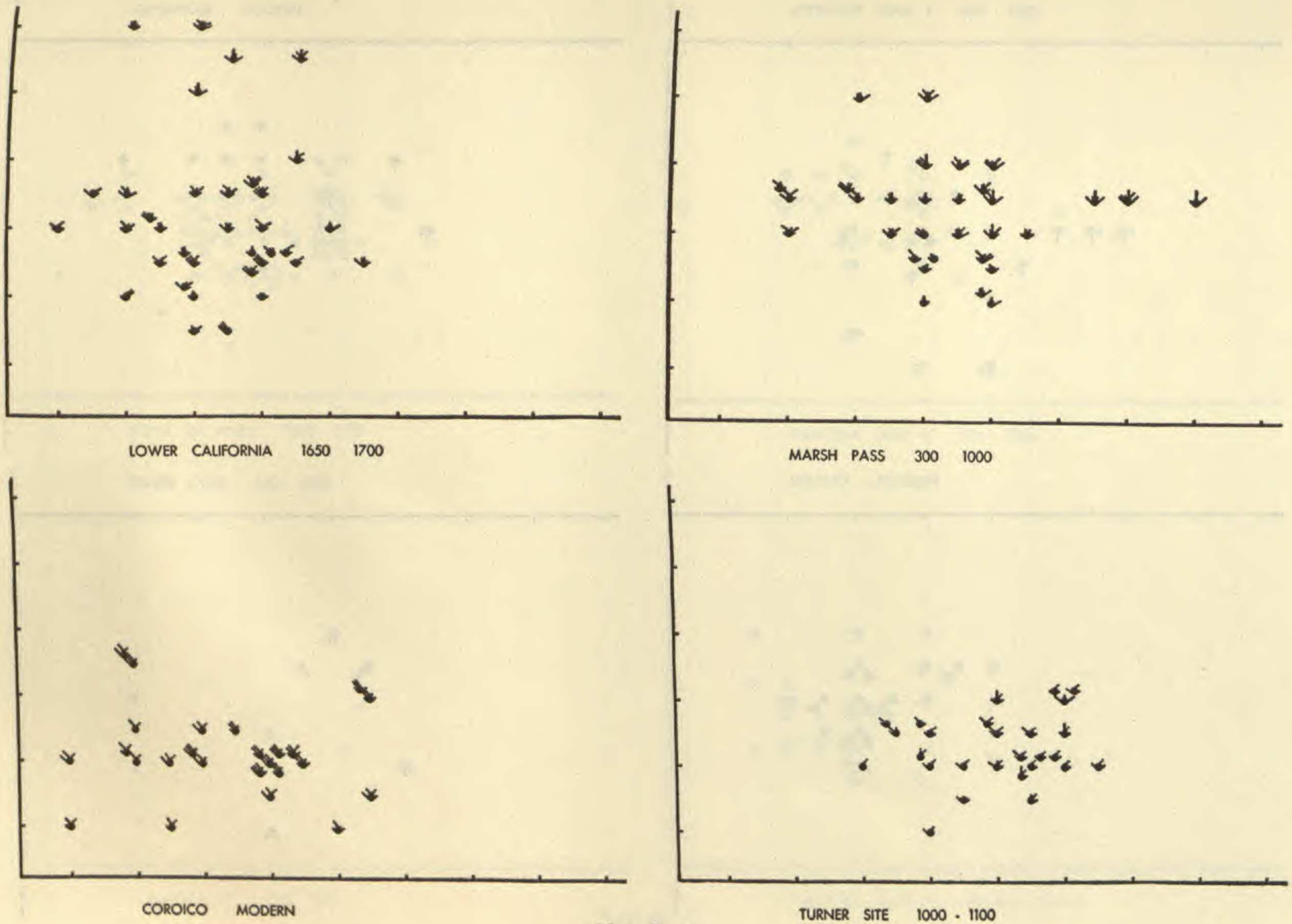
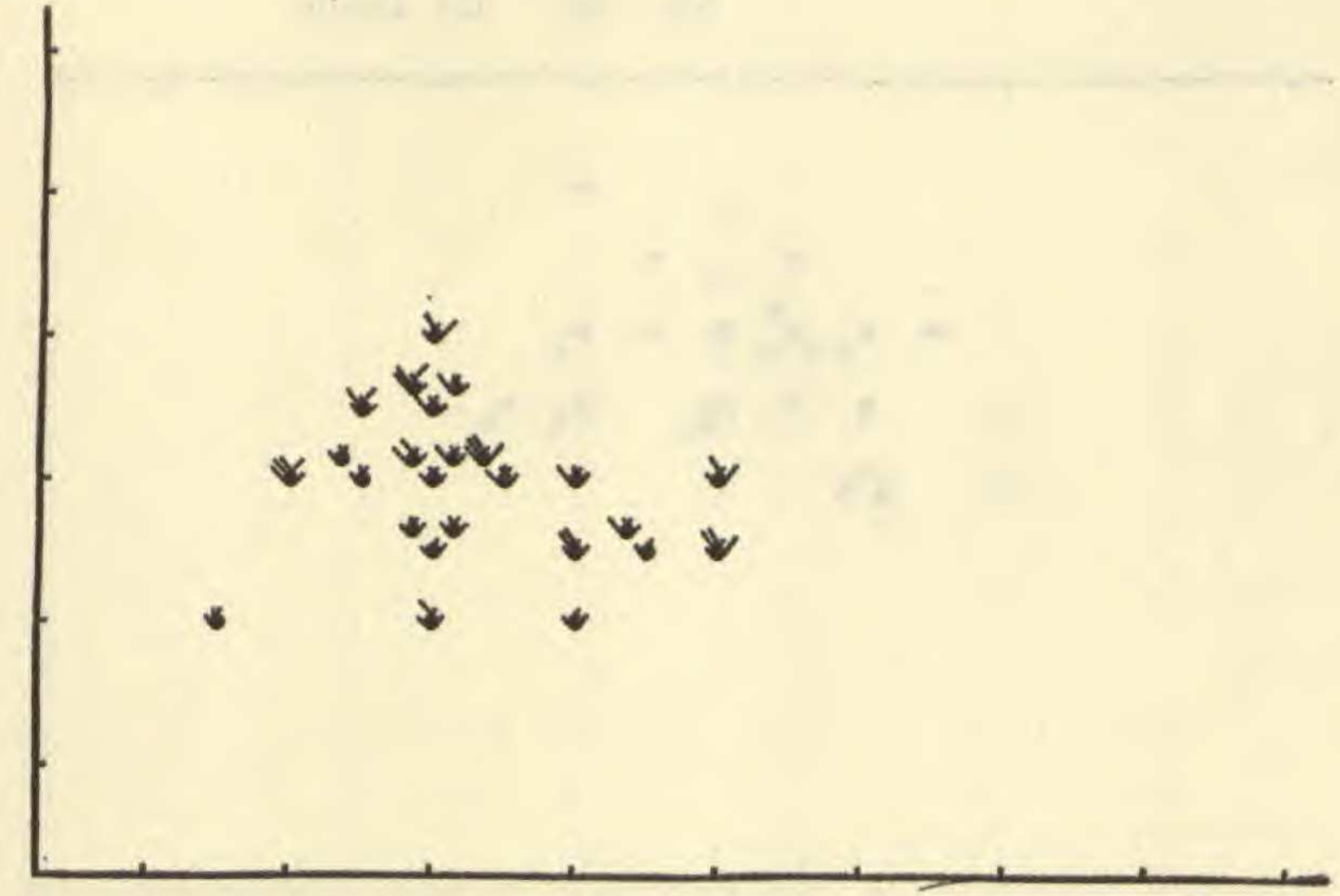
HOPI WHITE FLOUR MODERN
GUATEMALA FLINT MODERN
PERU FLOUR MODERN

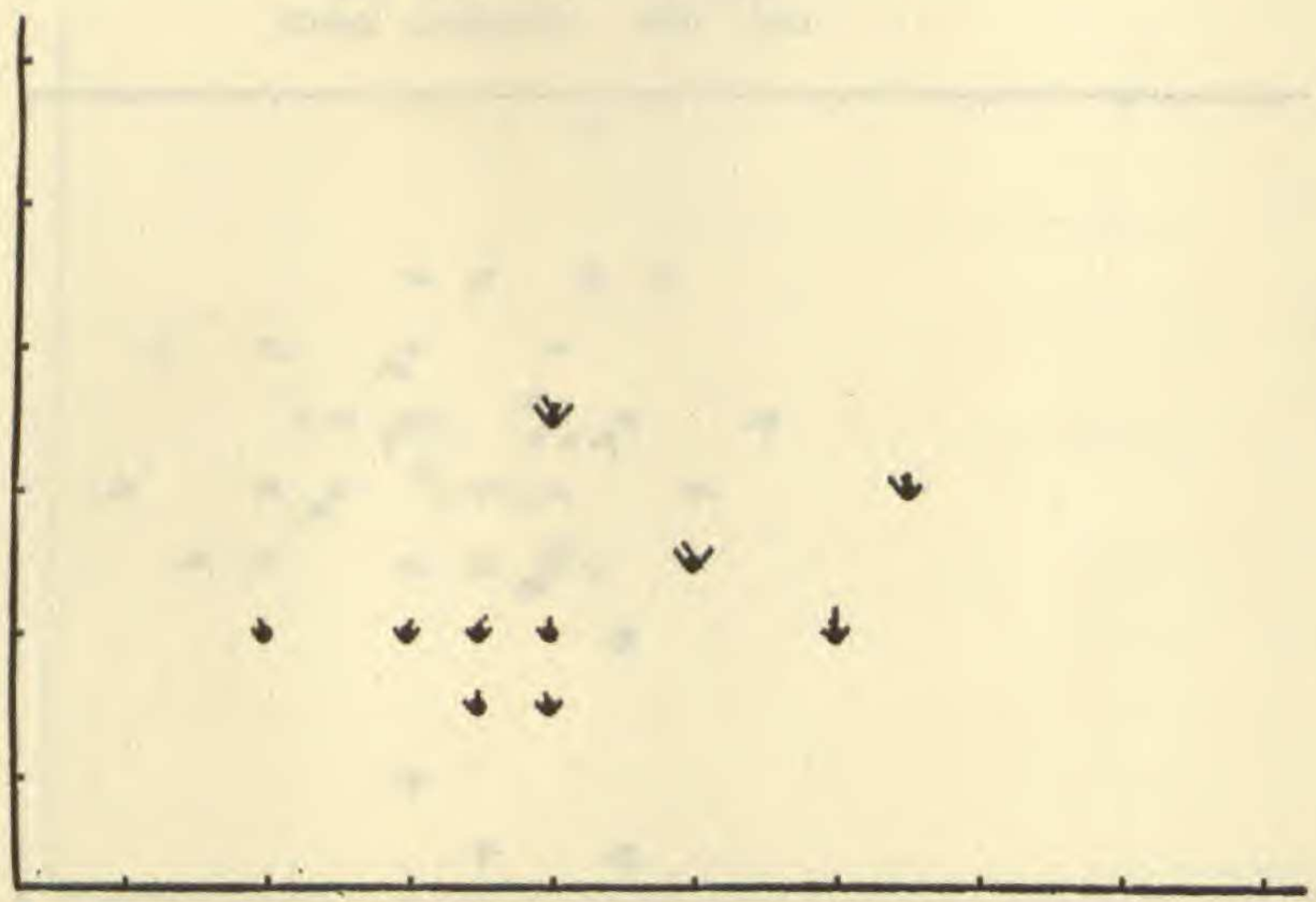

LOWER CALIFORNIA 1650 1700
MARSH PASS 300 1000
COROICO MODERN
TURNER SITE 1000 - 1100

Text-fig. 4

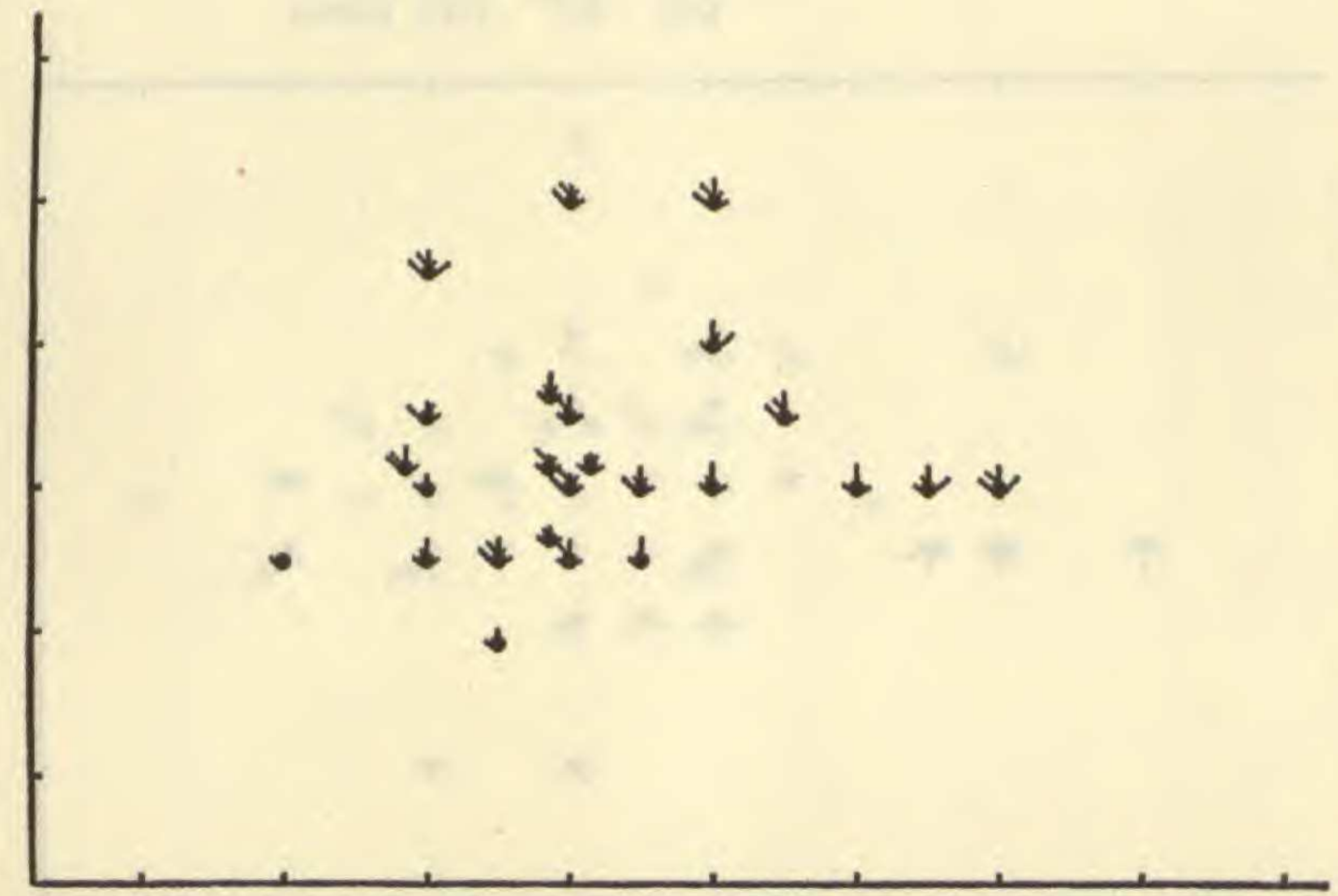
LUSTER CAVE 900 - 1000



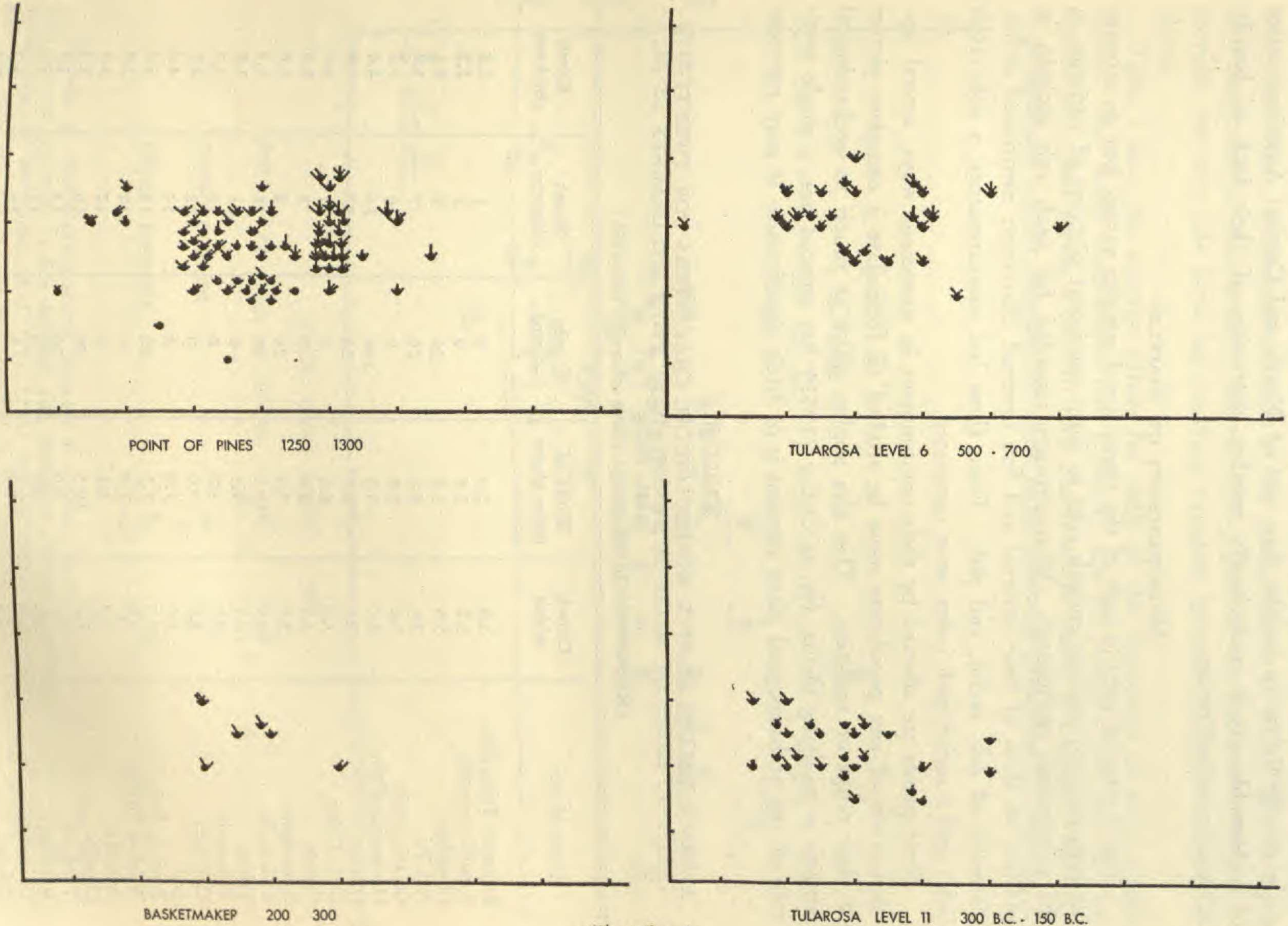
PAPAGO MODERN



CHAPALOTE MODERN



TULAROSA LEVEL 3 900 - 1000


POINT OF PINES 1250 1300
TULAROSA LEVEL 6 500 - 700
BASKETMAKEP 200 300
TULAROSA LEVEL 11 300 B.C. - 150 B.C.

Text-fig. 5

conform to the same general description. They are tapered, 15–25 cm. in length, with a medium-sized shank and bore 14–16 rows of narrow kernels. That they are markedly lighter in weight than ears of North and Central American maize of comparable size is undoubtedly another expression of their lack of heavily sclerenchymatized tissues.

Measurements of Samples

The number of cobs in each of the above-listed samples varied, but an attempt has been made to examine enough cobs to form consistent pictures of variation in the populations represented. Measurements recorded for each cob include, in addition to those of four external and five internal characters mentioned earlier, diameters of cob, rachis, and pith. From these last measurements, a cob/rachis index and a rachis/pith index were computed.

Since plants are affected by their environment in numerous ways, several representatives of any population must be studied to formulate a complete picture of their range of variation. This idea applies quite as much to archaeological remains as to living plants, for, as Cutler (1952) has pointed out, a single specimen of any archaeological plant remains is of little significance; it may represent

TABLE II

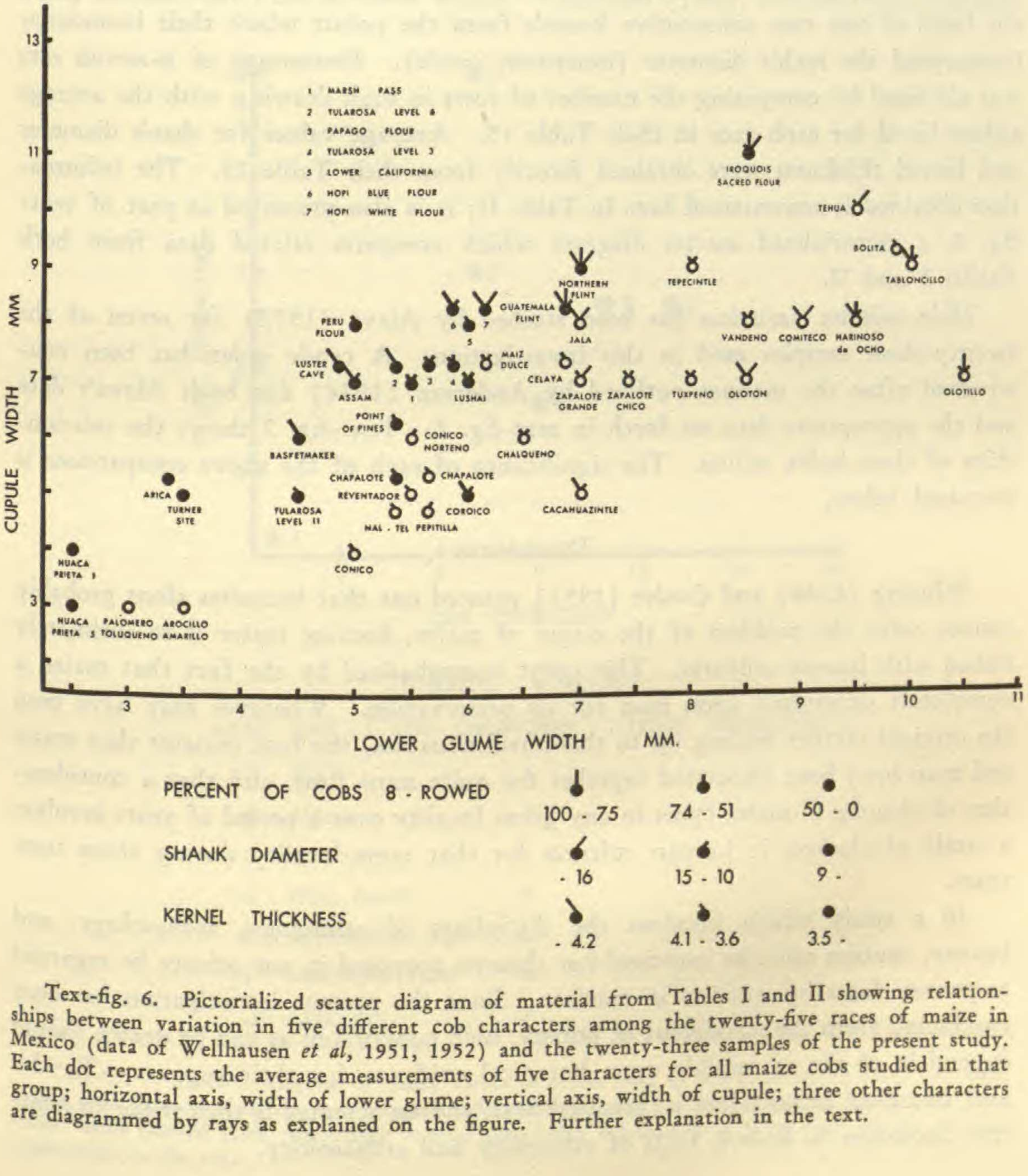
AVERAGE VALUES OF FIVE MORPHOLOGICAL CHARACTERS FOR TWENTY-FIVE EXISTING RACES OF MAIZE IN MEXICO (DATA FROM WELLHAUSEN *ET AL*, 1951, 1952).

(Measurements in mm. except where otherwise indicated.)

Name of race	Cupule width	Width of lower glume	% cobs 8-rowed	Shank diameter	Kernel thickness
Palomero Toluqueño	3.0	3.0	0	8	2.8
Arocillo Amarillo	3.5	3.5	0	8	2.5
Chapalote	5.5	5.5	20	9	4.1
Nal-Tel	5.0	5.5	20	7	3.9
Cacahuazintle	5.0	7.0	0	10	5.2
Harinoso de Ocho	8.0	9.5	100	14	4.4
Olotón	7.0	8.5	20	17	6.0
Maíz Dulce	7.0	6.0	0	11	4.0
Cónico	4.0	5.0	0	8	3.6
Reventador	5.0	5.5	20	8	3.6
Tabloncillo	9.0	10.0	90	11	4.3
Tehua	10.5	9.5	0	21	3.9
Tepecintle	9.0	8.0	0	10	3.7
Comiteco	8.0	9.0	0	22	4.5
Jala	8.0	7.0	0	34	4.6
Zapalote Chico	7.5	7.5	20	13	3.6
Zapalote Grande	7.5	7.0	0	18	3.8
Pepitilla	5.0	5.5	0	12	3.5
Olotillo	7.5	10.5	90	10	3.9
Tuxpeño	7.5	8.0	20	13	3.7
Vandeño	8.5	8.5	0	13	3.6
Chalqueño	6.0	6.5	0	10	3.9
Celaya	7.5	7.0	20	9	3.9
Cónico Norteño	6.0	5.5	0	11	3.5
Bolita	9.0	10.0	50	9	4.1

an accidental deposition, or it may have been buried in an old layer or brought to a recent one by rodents, pot hunters, or a recent occupant of the site. To minimize these effects, arithmetic averages of the measurements of each character have been computed for each sample. Alava (1952) pointed out that such a technique provides the only safe basis for studying variation between different varieties of plants.

Table I lists the average values for each of the characters of each sample studied. Ear shape contributed two columns, one for straight ears and one for tapered ears, thus giving a total of nine characters in which to compare variation. A pictorialized scatter diagram of these same results is presented in text-fig. 2.



Text-fig. 6. Pictorialized scatter diagram of material from Tables I and II showing relationships between variation in five different cob characters among the twenty-five races of maize in Mexico (data of Wellhausen *et al*, 1951, 1952) and the twenty-three samples of the present study. Each dot represents the average measurements of five characters for all maize cobs studied in that group; horizontal axis, width of lower glume; vertical axis, width of cupule; three other characters are diagrammed by rays as explained on the figure. Further explanation in the text.

Text-figs. 3, 4, and 5 show the variation and relationships of these same nine cob characters within each sample of cobs. The method of construction, as well as the general usefulness and reliability of these diagrams, is further discussed below.

An attempt was made to compare the results of this investigation with those obtained by Wellhausen *et al* (1951, 1952) for races of maize in Mexico. Several of the major characters employed in the present study were not employed by Wellhausen and his co-workers. However, their paper contained excellent diagrams of cross-sections of ears of each race drawn to scale; it was possible to make certain measurements directly from these diagrams. Lower glume width in mm. was measured at the widest point indicated on the third concentric circle of each ear diagram. Cupule width in mm. was measured as a straight-line distance across the bases of any two consecutive kernels from the points where their boundaries intercepted the rachis diameter (innermost circle). Percentage of 8-rowed ears was obtained by comparing the number of rows in each drawing with the average values listed for each race in their Table 15. Average values for shank diameter and kernel thickness were obtained directly from their Table 15. The information obtained is summarized here in Table II; it is also presented as part of text-fig. 6, a pictorialized scatter diagram which compares related data from both Tables I and II.

Male spikelet variation has been studied by Alava (1952) for seven of the twenty-three samples used in this investigation. A crude index has been constructed after the manner outlined by Anderson (1936) for both Alava's data and the appropriate data set forth in text-fig. 2. Text-fig. 7 shows the relationships of these index values. The significance of each of the above comparisons is discussed below.

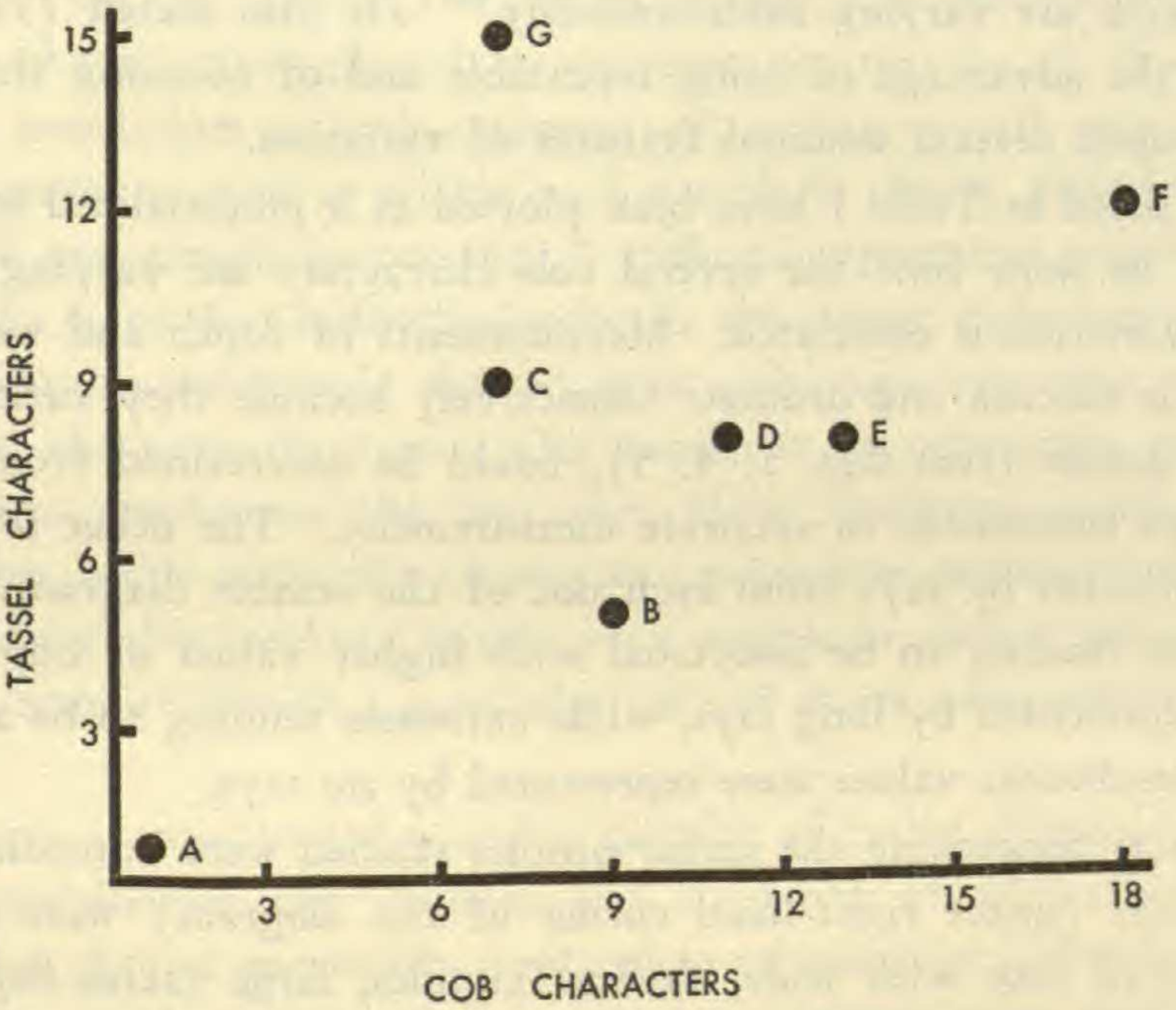
Discussion

Whiting (1944) and Cutler (1951) pointed out that botanists alone probably cannot solve the problem of the origin of maize, because maize is so intimately linked with human cultures. This point is emphasized by the fact that maize is completely dependent upon man for its preservation. Whatever may have been the original factors leading up to this novel situation, the fact remains that maize and man have been associated together for quite some time, and that a consideration of changes in maize types in any given locality over a period of years involves a study of changes in human cultures for that same locality during those same years.

In a study which involves the disciplines of ethnology, archaeology, and botany, caution must be exercised lest theories proposed in one science be regarded as proven facts by workers in another. Since the present investigation has been conducted from the standpoint of botany, such conclusions as can be drawn should depend in so far as possible upon botanical evidence for their support. To this end, botanical information is discussed first, and an attempt is then made to relate this discussion to known facts of ethnology and archaeology.

Botanical Aspects of Maize Cob Analysis

Variation among races of maize is nowhere better illustrated nor more difficult to describe than that found among female inflorescences, or cobs. Within any race, many cobs possess characters the measurements of which lie well within the range of variation of the same measurements from several other races. This exasperating fact is true for all the characters used in this study. Using any one cob character at a time, it is nearly impossible to distinguish races of maize; it is for this reason that the empirical classification of maize by kernel types proposed by Sturtevant (1899) is not of much value to modern maize breeders. Mangelsdorf and Reeves (1939) used evidence from several sources to characterize maize from different parts of the New World. Anderson (1946, 1947a), Anderson and



INDEX VALUES

MAIZE	RACE	COB CHARACTERS	TASSEL CHARACTERS
A	ARICA	1	1
B	ASSAM	9	5
C	CHAPALOTE	7	9
D	PERU FLOUR	11	8
E	GUATEMALA FLINT	13	8
F	NORTHERN FLINT	18	12
G	PAPAGO	7	15

Text-fig. 7. Scatter diagram of index values of seven races of maize in which both the tassel (male inflorescence) and the cob (female inflorescence) have been investigated. Horizontal axis, index values derived from cob study; vertical axis, index values derived from tassel study. Further explanation in the text.

Cutler (1942), Mangelsdorf and Smith (1949) and Wellhausen *et al* (1951, 1952) have used an increasing number of subtler characters in distinguishing both modern and prehistoric races of maize.

Pictorialized scatter diagrams (Anderson, 1949b) are a means by which several such variable characters can be considered at once, thereby emphasizing consistent and typical differences as well as similarities among the particular entities involved. Methods by which a pictorialized scatter diagram is developed are explained by Anderson (1949b, 1952) and Anderson and Gage (1952). Anderson (in press) has discussed the biological and mathematical criteria upon which pictorialized scatter diagrams are based. The value of such diagrams has been emphasized by Stebbins (1952), who considered the method "by far the best yet devised for making the observer aware of a pattern of variation in respect to three or more characters which are varying simultaneously." He also stated (1952) that the method "has the advantage of being repeatable and of focusing the attention of the observer upon certain essential features of variation."

The data listed in Table I have been plotted as a pictorialized scatter diagram (text-fig. 2) to show how the several cob characters are varying and to what extent their variation is correlated. Measurements of depth and width of cupule were chosen as abscissa and ordinate respectively because they varied consistently within each sample (text-figs. 3, 4, 5), could be ascertained from fragmentary cobs, and were susceptible to accurate measurement. The other seven characters were then indicated by rays from each dot of the scatter diagram. Extremes of each character tending to be associated with higher values of cupule width and depth were represented by long rays, while extremes tending to be associated with lower ordinate-abscissa values were represented by no rays.

Several facts concerning the maize samples studied were immediately apparent. At one extreme (upper right-hand corner of the diagram) were predominantly straight 8-rowed cobs with wide, shallow cupules, large rachis-flaps, wide lower glumes, heavy shanks, and thick or moderately thick kernels. This complex of characters was found in Northern Flint and Iroquois Sacred Flour; occurrence of endosperm as flinty or floury is dependent upon a single gene and is therefore of no significance here. These results agreed with those found by Brown and Anderson (1947) for typical Northern Flint varieties; the same complex was identified by Carter and Anderson (1945) as the Eastern complex. At another extreme (lower left-hand corner of the diagram) were cigar-shaped cobs with high row numbers, narrow deep cupules, small rachis-flaps, narrow lower glumes, small shank diameters, and thin kernels. These characters were associated in prehistoric maize recovered at Huaca Prieta, Peru, and Arica, Chile. It is significant that the majority of cobs were essentially complete but only about 5 cm. long. As a whole, these samples were remarkably homogeneous (text-fig. 3). Existence of a third extreme (middle left area of the diagram) is indicatd by tapered cobs with high row numbers, extremely deep cupules, little rachis-flap development, wide lower glumes, medium shank diameters, and thick or moderately thick kernels. The two maize samples from Asia were responsible. Cobs studied were those grown by Stonor in Asia; varieties involved were described by Stonor and Anderson (1949).

The most striking features of the Asian corn cobs were their extremely deep cupules and their particular form of sclerenchymatization. The rachis tissue and lower glumes of all Asian cobs studied were quite hard, but their hardness was not identical with that of "bony" rachis tissue described by Mangelsdorf and Smith (1949) in connection with teosinte introgression. Whatever its cause, the end product was an extremely stiff, light-weight bulky cob. Studies by Lenz (1948) did not indicate that cell wall thickness had much to do with degree of sclerenchymatization among various races of maize. A deep cupule could possibly be interpreted as a condition which showed little if any "Tripsacoid influence" (Cutler, 1946). An inference cannot be drawn that all Asian maize varieties are alike in this respect, but for both Assam and Lushai samples, this conclusion seems justified.

The nine characters employed in constructing text-fig. 2 showed a strong tendency for association at both extremes. A strong overall association between all sample averages as well as within each sample is clearly shown by comparing the average of any sample in text-fig. 2 with its appropriate population diagram in text-figs. 3, 4, or 5. Individual cobs in the upper right-hand area of each population diagram consistently showed more and longer rays than did those from other parts of the same diagram. This similarity of separation patterns in the several diagrams emphasizes the fact that those limits employed in separating sample averages, while originally chosen in a subjective taxonomic fashion (Stebbins, 1952), were also working within each sample in such a way that morphological trends associated with a particular race of maize were associated with each other.

The diagram as constituted contains samples of rather diverse races of maize; closeness of position on the diagram and similarity of glyphs indicate similar morphology but do not necessarily imply close relationship. Weatherwax (1936) stated that no sound basis exists for any attempt to trace maize origin by arranging varieties from different localities in an evolutionary sequence. Introduction of the dimension of time in the form of archaeological material, however, allows the investigator to arrange maize varieties of both present and past according to cultural succession; the result may or may not be an evolutionary sequence, but such an arrangement is the strongest means available for documenting maize history and has therefore been employed in this investigation whenever possible.

Results obtained in this investigation are compared below with those obtained in three other independently conducted investigations. A high degree of correlation is found in each instance, a fact which indicates a basic soundness in methods employed for cob analysis in this investigation.

Brown *et al* (1952) have discussed relationships among three varieties of Hopi maize, two of which, Hopi White Flour and Hopi Blue Flour, were included in the present study. These workers found that the two varieties had certain resemblances to Basketmaker and Eastern maize as well as to each other. Unfortunately, it was not possible to obtain a large enough sample of Kokoma, the variety they reported as resembling Basketmaker most closely, to warrant its inclusion here. Text-fig. 2 indicated that Hopi Blue Flour was basically similar to Basketmaker, differing in cupule width, wide lower glumes, heavy shanks, and presence of 8-rowed cobs. It should be noted that there has been no change in cupule depth and predominance of cigar-shaped ears in development of Hopi Blue Flour from Basketmaker maize.

Hopi White Flour was found by Brown *et al* (1952) to contain an admixture of both Eastern and Mexican germ plasm. The Mexican complex (Carter and Anderson, 1945), known to be present on the Mesa Central of Mexico, is characterized by strongly tapered cobs with high row numbers, thick kernels, and small shanks. This conclusion was borne out by text-fig. 2, which showed Hopi White to have all the characters associated with the Eastern complex with the exception of row number and cob shape; tapered cobs of high row number may be attributed to Mexican influence. Cobs of these two Hopi Flour maizes differed from each other in cupule depth (text-fig. 2 indicates this to be the strongest character contributed by the Eastern complex), cob shape, shank diameter, rachis-flap height, and row number.

In the correlation between results obtained in the present investigation and those of Wellhausen *et al* (1951, 1952) which are listed in Table II, the number of characters used was less than the number employed to separate the samples listed in Table I; yet, a pictorialized scatter diagram (text-fig. 6), using five measurements, presented essentially the same variation pattern as did text-fig. 2, in which nine measurements were employed. It should be noted that the basic pattern of maize cob variation was not altered by using measurements of a different character for the abscissa of text-fig. 6 than that employed in text-fig. 2. If a sample on text-fig. 6 has any real affinity to races with which it may be allied on other grounds, the fact should be shown by its position on the diagram. Text-fig. 6 should also lend further confirmation to the genealogies postulated by Wellhausen *et al* for several hybrid races of maize. That these confirmations are indeed possible was shown quickly and easily. The four races classified by these workers as Ancient Indigenous Races (Palomero Toluqueño, Arocillo Amarillo, Chapalote, Nal-Tel) were closely grouped; moreover they were all placed in the lower left-hand corner of the diagram and all had few to no rays. Thus their characters of small cupules, narrow lower glumes, high row numbers, thin kernels, and small shanks, all believed to indicate primitiveness in relation to other races of maize here considered, were strikingly indicated by text-fig. 6.

Three of the four races classified as Pre-Columbian Exotics (Cacahuazintle, Harinoso de Ocho, Olotón, Maíz Dulce) formed a consistent graded series along the lower edge of the upper region of text-fig. 6. They were placed in a separate class because of their antiquity and resemblance to South American maize. While the class was somewhat artificial, the positions of three of its four constituents on the diagram in a nearly perfect ascending order indicated a basic similarity in variation pattern.

From these races a group of thirteen Prehistoric Mestizos and a group of four Modern Incipient races were thought to have arisen. For many of these, Wellhausen *et al* compiled a chart showing the two putative parents of the particular race under discussion. Out of a total of eleven genealogical relationships involving other races plotted on text-fig. 6, seven were found to be borne out by diagram position, being for the most part midway in both position and number of rays. These genealogical relationships as postulated by Wellhausen *et al* are listed below. Group 1 is comprised of those races whose positions on text-fig. 6 offered further proof of relationship to their putative parents. Group 2 is comprised of those races whose positions on text-fig. 6 did not approximate positions between their putative parent races.

GROUP 1

Cónico	Palomero Toluqueño	×	Cacahuazintle
Zapalote Chico	Nal-Tel	×	Tepecintle
Chalqueño	Cónico	×	Tuxpeño
Cónico Norteño	Celaya	×	Cónico
Bolita	Zapalote Chico	×	Tabloncillo
Tuxpeño	Tepecintle	×	Olotillo
Comiteco	Tehua	×	Olotón

GROUP 2

Zapalote Grande	Tehua	×	Zapalote Chico
Vandeno	Tuxpeño	×	Zapalote Grande
Celaya	Tabloncillo	×	Tuxpeño
Jala	Tabloncillo	×	Comiteco

The fact that a majority of such genealogies can be substantiated by arranging data obtained from the cobs alone is added proof that races may not only be recognized by cob characters, but that their histories can also be ascertained in the same manner with a high degree of accuracy. It should also be borne in mind that data for the Mexican samples represented averages determined from 3–5 cobs of each race; the accuracy might well have been increased had more cobs been used in determining average values. Text-fig. 6 further showed that variation in Mexican maize followed the same general pattern of character association as did variation among the samples employed in this investigation, and that prehistoric North and South American samples were close to the primitive Mexican races.

Spikelet variation in *Zea Mays* was studied by Alava (1952), using methods which, while applicable to male inflorescences, were of no use in the investigation of maize cobs. Thus if any correlation between results of two independently conducted investigations should exist, it would not only be further substantiation for validity of methods employed and results obtained, but also would indicate that cob and tassel analyses yield comparable results. Similar material from seven different races was examined in each investigation. A numerical index (Anderson, 1936; Stebbins, 1952) for both cob and tassel characters was computed for each race. While admittedly a crude indicator of morphological characters, numerical indices are valuable for summarizing diverse data in a manner which permits direct comparisons to be made. Text-fig. 7 shows the extent of this correlation. Arica had the smallest value in both indices, and there was a general progression toward the upper right-hand corner of the graph occupied by Northern Flint. Papago appeared somewhat aberrant as far as tassel index was concerned, but came closest to Chapalote, a related race, in both values. Peru Flour and Guatemala Flint were close, a further expression of their presumed relationship to one another. Guatemala Flint was closer to Northern Flint for cob-index value. Although a considerable number of units away, Asian material was closest to Arica in both cob and tassel values. Thus with the possible exception of Papago, in which variation is unique but consistent with its past history, the samples showed high correlation between tassel and cob morphology in distinguishing races of maize.

Maize Cob Analysis in Relation to Ethnology and Archaeology

Knowledge of ancient peoples is in large part built upon a detailed study of their refuse heaps; rubbish being what it is, a place is assured for the botanist in archaeological analysis. Analysis of maize remains is especially helpful, since few other plants have become so closely associated with man to the extent that they are reliable indicators of his early history in many parts of the New World.

SOUTH AMERICA AND ASIA

Lowie (1940) pointed out that it was a common mistake to identify all early agriculture with maize. Sauer (1952) contended that seed-crop agriculture was developed after a root-crop agriculture which involved vegetative propagation only. Excavations in northern Chile (Bird, 1943), and more especially in Peru (Bennett, 1948; Bird, 1948), showed that there were indeed agricultural communities without maize. Layers of middens at Huaca Prieta, Peru, beginning about 4000 years ago, contained squash, beans (4 types), chili peppers, *Canna*, cotton, and bottle gourds (*Lagenaria siceraria*, Whitaker and Bird, 1949). Maize did not appear until 850 B.C. Whitaker (1948) pointed out that it is extremely difficult to account for the bi-hemispheric distribution of *Lagenaria*, as it is presumed to be of Asiatic origin. Partly on such distributional patterns, Carter (1950) postulated pre-Columbian contacts between the Old and New Worlds, a theory also put forward by Stonor and Anderson (1949) and Sauer (1952). That it was quite possible to sail in either direction across the broad expanse of the Pacific has been amply documented by Buck (1938).

Another odd fact about prehistoric plants of west-coast South America is that they are presumed to be native to Central America. Either these plants reached the coast as articles of trade among established peoples, or they were taken there by the first settlers of the area, who either came from or passed through the Central American region. It does not seem possible that maize would have been overlooked by these peoples as a crop plant had they passed through an area in which it was growing or being grown. Yet evidence on the possible antiquity of maize in central Mexico was recently reported by Barghoorn (1952). Maize pollen has apparently been recovered from sedimentary deposits under Mexico City which may antedate human occupation. Recently, however, the date of human occupation has been pushed back to 9000 years in the same area (Richards, 1953).

A type of maize hitherto not mentioned in this investigation is that which is generally referred to as popcorn. True pops are generally of quite primitive morphology (Mangelsdorf and Smith, 1949). Prehistoric Arica and Huaca Prieta maize remains may quite possibly be those of popcorns; Wissler (1945) showed that this is true for some whole maize ears excavated at Arica. In ear shape and size and in tassel characters (Alava, 1952), these prehistoric remains were comparable to a modern pop variety collected by Parodi in Argentina. They may also be related rather closely to Asian types, since they had deep cupules, high row numbers, and some tapered cobs. Tassel analysis (Alava, 1952) also showed an Asian similarity. The above evidence is suggestive, but it also indicates the necessity for more data before the history of maize in both South America and Asia can be considered to be completely known.

THE AMERICAN SOUTHWEST

Maize in the American Southwest has had a long and complicated history. Man was present in the area 10,000 years ago (Wormington, 1949; Johnson, 1951) but there was little evidence that the area was under continuous occupation from that time until the advent of agriculture. Randolph (1952) stated that an apparently humid and subtropical climate existed there 5,000–10,000 years ago, and that the area itself could be the original home of maize. Carter (1945) likewise postulated the Southwest as a center of agricultural dispersal. All known archaeological remains which contain maize are younger than 5,000 years, so the problem at present is to evaluate the evidence at hand. It should be kept in mind that whatever statements are made below are subject to revision in the light of further discoveries.

Carter and Anderson (1945) noted three major cultural provinces in the Southwest: Hohokam, Mogollon, and Anasazi (Puebloan). At the time of their survey, little was known of the Mogollon civilization, but recent excavations at Tularosa and Cordova Caves (Martin *et al*, 1952) have produced evidence establishing this cultural province as one of equal importance with Hohokam and Anasazi. Archaeological maize is now known for each of the three cultural provinces. Hohokam maize was found in Ventana Cave, Arizona (Haury, 1950). It is similar to but not identical with modern Pima-Papago varieties (Carter and Anderson, 1945). Chapalote, an ancient Mexican race, is today found in northwestern Mexico, an area which was also part of the Hohokam cultural province (Amsden, 1949). Relationships between Papago and Chapalote have been discussed above. Since the Hohokam area was relatively isolated from influences of neighboring cultural patterns, the maize found there today is much the same as it was in ancient times. It is reasonable to assume that prehistoric maize in this cultural province was similar but not identical to that of Basketmaker and Mogollon cultures, and that modern Papago and Chapalote were derived from it. It was shown (text-fig. 2) that maize remains recovered from Tularosa Cave Level 11 were quite similar to both Chapalote and Basketmaker. Similarity between Chapalote and Basketmaker II maize from Cottonwood Cave (Hurst, 1948; Hurst and Anderson, 1949) was pointed out by Wellhausen *et al* (1951, 1952). Amsden (1949) noted the similarity of modern Papago to Basketmaker, as did Carter and Anderson (1945). The present investigation showed that Basketmaker resembled Chapalote much closer than it did Papago, but the important point is that all three cultural areas, Hohokam, Anasazi, and Mogollon, had at an early date maize which was variable but essentially similar. Maize of the Hohokam area remained relatively unchanged; that of the other two areas was strongly influenced by maize from more remote places. Text-fig. 5 illustrates the variable nature of early southwestern samples. In contrast to maize of the Southwest, remains from Arica, Chile, and Huaca Prieta, Peru, are very homogeneous; furthermore, maize of these two areas (American Southwest and South American West Coast) were contemporary. Explanation of the variability in the one location and homogeneity in the other at the same time is but one of the many problems of maize history.

Basketmaker maize was widespread, having been reported from several sites in the Anasazi area. Some of the better known sites are Cottonwood Cave, western Colorado (Hurst, 1948; Hurst and Anderson, 1949), Mummy Cave, Cañon del Muerto, Arizona (Anderson and Blanchard, 1942), and Painted Cave, northeastern Arizona (Haury, 1945). Basketmaker-like maize was reported outside the Anasazi area by Brown and Anderson (1947) in prehistoric remains of rock shelters and caves from the Ozarks to southern Ohio.

Two combinations of maize characters, one peculiar to the Mexican Mesa Central and the other to the eastern United States, were superimposed in varying amounts on southwestern maize. The spread of each influence may be traced by analysis of successive samples; in such work, the importance of dated maize remains can hardly be over-emphasized. Mexican influence is characterized by strongly tapered cobs with high row numbers (Carter and Anderson, 1945), thick kernels, and small shanks. This type entered the Southwest from the Northeast rather than from Mexico directly; its greatest influence has been found in remains of the Fremont Basketmakers of Yampa Canyon, Utah, dated at 400–800 A.D. (Burgh and Scoggin, 1948).

At Luster Cave, in extreme eastern Utah, maize was subjected to strong Eastern influence prior to 1000 A.D. Text-fig. 2 showed this sample to be closely related to Hopi White Flour among ethnological races examined in this study. Hopi White Flour differed, however, in being more extreme for certain Mexican (tapered ears, high row numbers) and Eastern characters (large shanks, wide lower glumes). Maize from the Davis Site (Newell and Krieger, 1949) was analyzed by Jones (1949) and found to be entirely Eastern. These maize remains were dated at about 700 A.D. by Jones and at about 400 A.D. by Johnson (1951).

The question of origin of Eastern influence has long been a puzzling one. Anderson (1947a) and Brown and Anderson (1947) presented evidence that Eastern maize is related to Guatemalan maize. Jones (1949) reported that he and Krieger independently reached the conclusion that both maize and pottery types recovered at the Davis Site bore a resemblance to those of Guatemala. Carter (1946) suggested that maize could have been carried up the east coast of Mexico or across the Gulf to southern United States. Regardless of the method employed, this movement must have taken place in time for the influence to have been carried to the Southwest by 1200 A.D., a date which Carter and Anderson (1945) recognized as closely approximating its first appearance in that region. Judson (1951) called attention to the fact that a great drought occurred in the Southwest in 1276–1299 A.D., and that many Indian tribal migrations took place around that time. The direction of movement of maize into the Southwest was from east to west; Carter and Anderson (1945) noted that among the present-day Puebloan tribes, those of eastern pueblos have more eastern-like maize than do those of western pueblos. It is generally accepted that there is influence of Plains cultures in the southwestern area. This influence also is stronger in eastern pueblos than in western ones, and is another indication of how well maize history is correlated with the history of the peoples who grew it.

THE AMERICAN SOUTHEAST AND EAST

Wherever the Eastern complex came from, it was probably carried up the river valleys of the Mississippi and its tributaries by Indian tribal migrations. A date of 900 A.D. was assigned to the earliest known Burial Mound I culture by Ford and Willey (1941), who also identified the beginnings of horticulture in eastern United States at this time. Burial Mound I peoples were in turn supplanted by Burial Mound II and later (1200–1400 A.D.) by Temple Mound I and Temple Mound II cultures. Ford and Willey derived the Iroquois culture of New York from a welding of these four intrusions onto an archaic hunting-gathering population; they considered that this and other allied upper Mississippian cultures reached a peak after 1500 A.D., and lasted until historic times. Although other evidence has been presented in support of the idea that maize was a late arrival in eastern woodland cultures (Linton, 1924; Kroeber, 1939), from a botanical point of view the postulated time of arrival of maize in this area appears too recent. This impression is strengthened by consideration of the length of time the same type of maize was present in the Southwest.

Recent radiocarbon dating (Johnson, 1951) indicated that Mississippi valley and other eastern cultures were of greater antiquity than had previously been thought. Johnson (1951) reported that Hopewell sites from Ohio and Illinois were about 1000 years older than had previously been estimated. The whole chronology of the Southeast has become unsettled because of radiocarbon dating results, but the presence of cultures in this area at earlier dates further strengthens the idea that maize is of greater antiquity than had been thought possible, and opens a way to minimize a long-standing inconsistency between archaeological and botanical evidence.

Since there was, as Ford and Willey (1941) and Waring and Holder (1945) pointed out, a suggestion of strong Mexican influence in Temple Mound I and II cultures, the idea would be greatly substantiated should remains of Mexican maize ultimately be found in excavations. Botanical evidence exists that maize of the Southeast is related to a Mexican Gulf Coast race (Wellhausen *et al*, 1951, 1952), and hybridization of this Mexican maize with eastern flint maize already present in the Southeast probably resulted in the variable forms called Southern Dents by Brown and Anderson (1948).

Northern Flint and Southern Dent maizes were subsequently brought together to form modern hybrid corn-belt maize (Anderson and Brown, 1952a, 1952b). A significantly large collection of Southern Dents was not available for inclusion in the present study, but the few available cobs which were studied showed a rather close resemblance to Northern Flints in cob characters. Evidence that many Southern Dents were intermixed with Northern Flints was presented by Brown (1949), who studied chromosome knob numbers in United States maize. He found Northern Flints to have the lowest knob numbers, Southern Dents the highest, and corn-belt forms intermediate between these extremes. Longley (1938) had previously surveyed Indian maize varieties from the United States and northern Mexico. He reported the same general rise in knob number among southeastern varieties. He also found that maize of Arizona and New Mexico was high in knob number. Carter (1949) used knob numbers on chromosomes of Indian maize to indicate tribal affinities and differences. The fact that such an investigation yielded results substantially the same as those of different approaches is another example of how closely maize mirrors the history of those with whom it is associated.

An important point regarding use of Northern Flint and Southern Dent maizes in corn-belt maize production is that the hybrid vigor manifest in this cross is based upon small differences between two already-intermixed races. This situation may possibly indicate that improvement of maize by hybridization techniques has barely begun. Since identification and classification of races are becoming a necessary part of maize breeding, a knowledge of cob variation should be of practical value in the development of new strains of hybrid maize. The principles of cob analysis set forth above, even though they employed small morphological differences, may be considered fundamentally sound, because results obtained from their analysis were in agreement with ethnological and archaeological as well as botanical data of other workers.

Summary

Morphological characters present in the female inflorescence, or cob, of *Zea Mays* L. have been measured on over 500 cobs representing both modern and archaeological varieties. External characters measured included row number, shank diameter, cob diameter, and over-all cob shape. Internal characters measured included cupule width, cupule depth, height of rachis-flaps, kernel thickness, lower glume width, rachis diameter, and pith diameter.

Analysis of pictorialized scatter diagrams of averaged measurements showed a high degree of association of these characters. These results agreed closely with those of previous investigations employing other methods. The results of archaeological maize analysis were in harmony with previous conclusions based on purely archaeological data. Such agreements indicate the validity of cob analysis for characterizing variation in races of maize.

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